

SR72-1080

FINAL REPORT

BIOMEDICAL GROUND
LEAD SYSTEM

NAS 9-11442

PREPARED FOR:

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
R&D PROCUREMENT BRANCH
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

PREPARED BY:

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AUGUST 22, 1972

Introduction

This report has been prepared in accordance with Article XIV of Contract NAS 9-11442. The contract consisted of the development and fabrication of Biomedical Ground Lead Systems by Spacelabs, Inc. for the Manned Spacecraft Center. The contract was in two parts, 10 prototype units and 50 production units.

Purpose

The Biomedical Ground Lead System (BGLS) was designed to replace the 2 megohm resistor used to limit current flowing in the ground electrode of the Apollo biomedical monitoring system. In addition to providing a low impedance path to ground, the BGLS serves to reduce noise and artifact of ECG signals.

Program Objectives

During Phase I of the program 12 BGLS were designed and fabricated by Spacelabs. Two of the units were subjected to design verification tests in accordance with Spacelabs Test Procedure 105069. This consisted of functional testing and exposure to random vibration and EMI environments.

No problems were encountered and the units were delivered to NASA.

Phase I was completed with the submittal of the Design Verification Test Report and prototype units to the customer.

Phase II consisted of the fabrication and testing of 50 production BGLS. The status of the 50 units was changed by Modification 3S to the contract

from flight to production. As a consequence of this no qualification testing was performed. The 50 units were delivered to NASA as Class II equipment.

A listing of significant dates and events follows:

Dec. 14, 1970	Contract awarded
Feb. 26, 1971	Preliminary Design Review Meeting held at Spacelabs
May 24, 1971	Design verification testing completed
June 4, 1971	Two DVT prototypes delivered to NASA
July 1, 1971	Ten prototype BGLS were delivered to NASA
Aug. 16, 1971	Option for 50 units of Phase II was exercised by NASA
Aug. 30, 1971	Two BGLS (S/N 003 and 007) were returned to Spacelabs for failure analysis
Nov. 9, 1971	A failure analysis report was delivered to the NASA Technical Monitor.
June 21, 1972	Spacelabs responded to the NASA request for deletion of flight qualified status on the hardware.
Mar. 17, 1972	Modification 3S was made to the contract.
May 22, 1972	Fifty BGLS were shipped to NASA

Contract Performance

The delivery of the 50 production BGLS was delayed by about three months due to delays in component procurement and test failures during high reliability parts testing. Modification 3S to the contract provided for the use of one untested part, the PF539 transistor, in the last 15 BGLS. The new parts were screened by the manufacturer for leakage, which was the problem discovered in the original lot of devices. The size of the BGLS was increased

from the 0.35 inch diameter by 1.0 inch long of the contract to 0.362 inch diameter by 1.110 inch long. This made assembly easier and reduced the probability of any repeat of the problem with the two prototypes which failed to current limit within specifications.

New Technology

There were no new technology items associated with the contract. This fact was certified in a letter to John T. Wheeler of NASA on August 2, 1972. The device was constructed using welded semi-cordwood construction, encapsulated in hard epoxy, similar to the Apollo bioinstrumentation built for NASA/MSC by Spacelabs for use in the Gemini and Apollo spaceflight programs.

Recommendations

It is recommended that on any future bioinstrumentation systems, the ground lead system be incorporated as an integral part of the signal conditioner(s). This would eliminate one component from the system while still providing ground lead protection for the crewman. It would also result in a cost saving for the government.

Conclusion

The remainder of this report consists of copies of the nine progress reports provided during the contract.

SPACELABS, INC.
MONTHLY PROGRESS REPORT NO. 1

This progress report covers the period from 12/14/70 to 3/31/71.

1. General Progress

The following tasks have been accomplished since receipt of the contract on 12/14/70.

- a. Electrical design has been completed.
- b. Procurement of parts was initiated.
- c. PDR was conducted at Spacelabs on 2/26/71. The minutes of the meeting are enclosed as Appendix A of this report.
- d. A complete set of documentation was sent to NASA for approval on 3/5/71.
- e. Six samples of the proposed strain relief technique were sent to NASA/MSD for testing.
- f. The acceptance test procedure was sent to NASA for approval on 3/24/71.

It is expected that all parts and materials will be in by 3/26/71. Production of the DVT prototypes is scheduled to start on 3/29/71. Delivery of the DVT test procedure is scheduled for 4/12/71.

2. Quality Assurance

- a. General - Spacelabs was visited twice by Mr. Dick McGrath of NASA Quality Assurance. On his second visit on March 9, 1971,

Mr. McGrath reviewed the proposed operation sheet and flow chart. Together with Mr. Bob Bouchard of DCAS Van Nuys, the necessary government inspection points were determined and indicated on the operation sheet and flow chart. Arrangements were made for notification of Mr. McGrath and Mr. Bouchard for inspection of the first unit built.

b. Documentation - Spacelabs submitted revised reliability and inspection program plans to NASA. Also, the preliminary FMEA was submitted along with preliminary EEE and non-metallic parts lists.

c. To be Accomplished Next Period - Components for prototypes will be inspected. Acceptance and development test procedures will be prepared and submitted to NASA. Evaluation of percussion welding techniques will be made and a process specification will be prepared.

APPENDIX A
PDR MINUTES

A. General

This report presents the minutes of the preliminary design review meeting conducted at Spacelabs, Inc. on February 26, 1971.

Following is a list of attendees to the meeting:

Spacelabs, Inc.

J. Adams
R. Kaeller
C. Lombardi

NASA

M. Lippitt

B. Mechanical Design Review

1. The mechanical design of the BGLS was discussed in detail. The following action items were established.
2. Spacelabs to send samples of strain and tensile relief to NASA within two weeks for test and evaluation. NASA to provide comments ASAP and a report within two weeks.

C. Marking

1. The following marking information was agreed upon:

BIO-MED-GND-LEAD-SYSTEM

Mfg. by Spacelabs, Inc.
Part No. 105061
S/N XXX
2. The serial number may be put on the shrink tubing or on the wire. This will also suffice as identification of one side of the BGLS from the other.
3. Shrink tubing may protrude 1/4" from the body of the unit.

D. Documentation

1. The following documents will be sent to NASA by 3/7/71.

Inspection Plan

Reliability Program Plan

FMEA

Assembly Drawings

Detail Drawing

Parts List

2. The DVT and acceptance procedure will be submitted to NASA 3/12/71.

3. The transfer characteristics analysis will be submitted to NASA by 4/4/71.

E. Miscellaneous

1. The total quantity of prototype units is 10 + 2 DVT per proposal. The two DVT units are to be delivered if not needed for any other type testing.
2. EMI testing to be performed in two modes, limiting and non-limiting.

PROGRESS REPORT NO. 2
AND FINAL REPORT
FOR ITEM 1 OF THE CONTRACT

Section 1

Progress Report No. 2

Section 2

Design Verification Test Report

Section 3

Acceptance Test Data

Section 4

Design Verification Test Data (electrical)

Section 5

EMI and Vibration Test Data

Section 6

Photographs

Spacelabs, Inc.
Contract NAS 9-11442
Biomedical Ground
Lead System (BGLS)
7/16/71

PROGRESS REPORT NO. 2
AND FINAL REPORT
FOR ITEM 1 OF THE CONTRACT

1. Introduction

This report is intended to serve two purposes. The first is to provide NASA/MSD with a summary of the significant events which have taken place on Contract NAS 9-11442 since the last monthly progress report of March 1971. The second purpose is to serve as a Final Report for the completion of Item 1 of the contract and to transmit an updated drawing package to the customer.

The general section of the report contains a chronological listing of significant progress events starting with April 1, 1971 and continuing through to the completion of Item 1 of the contract, delivery of ten prototype biomedical ground lead systems to NASA/MSD on July 1, 1971.

Following the progress section are sections which deal with problem areas, conclusions, and recommendations. Also included are sections for QA and reliability, documentation, and a set of the latest drawings for the BGLS. A copy of the Design Verification Test Report is included as an appendix to this report.

2. General

- a. April 1 - Spacelabs received the results of the NASA/MSC evaluation of the bend relief samples submitted in March, all components and material were received, and production was completed on the two design verification test prototypes.
- b. April 15 - Spacelabs received NASA/MSC comments on drawings submitted. Drawings were revised to incorporate the necessary changes.
- c. April 23 - In a telecon between Spacelabs and NASA/MSC it was determined that Spacelabs would request a waiver for any non-metallic materials used in the BGLS which are not flight approved and NASA/MSC will approve the request. This will be necessary for production of the 50 flight BGLS only.
- d. April 30 - Spacelabs received NASA/MSC comments on the acceptance test procedure. Changes were made and documents resubmitted. The percussion welding specification to be used for lead attachment was also submitted. Final assembly of the design verification test units was completed.
- e. May 7 - May 24 - Acceptance and design verification tests were completed on two BGLS.
- f. June 4 - The two design verification test units were shipped to NASA/MSC with all data except for Approved Engineering Test Lab report on EMI and vibration testing. Copies of the DVT report are included with this report.

g. June 4 to July 1 - Ten prototype BGLS were fabricated, tested, and delivered to NASA/MSC.

3. Problem Areas

a. Spacelabs requested and NASA/MSC approved a waiver on the diameter of the finished BGLS. This was necessary because the double thickness of nameplate and adhesive had not been considered when the diameter was initially established. A change to the contract and Spacelabs drawings will be necessary for fabrication of the 50 BGLS of Item 2 of the contract. The Spacelabs drawings 105061 and 105062 have been changed to reflect the as-delivered size.

b. The Spacelabs resistance welding specification, drawing 610101, Rev. B, was submitted to NASA/MSC by Dick McGrath, a local NASA QA representative. NASA/MSC reviewed the specification and compared it against MSFC-STD-271. This government specification is not a part of the contract and it was not the intent of Spacelabs to meet this specification in the welding of the BGLS. The Spacelabs specification has been used in the welding of all Gemini and Apollo flight hardware built by Spacelabs for NASA. The welding methods used by Spacelabs result in a reliable welded module at a reasonable cost. Spacelabs intends to use 610101 in the production of Item 2 of the contract. If any documentation approval problem still exists, it should be resolved prior to start of Item 2 production.

4. Conclusions

The results of testing the first 12 BGLS indicate that the design is adequate. No problems were encountered in the electrical, vibration, or electro-magnetic interference test phases. Some minor manufacturing difficulties encountered are discussed in the recommendations section of this report.

5. Recommendations

a. A lengthening of the final assembly to 1.10 inches would aid in assembly. Some difficulty was encountered when installing the end cap on the body because of the parts density and the bend relief caps. Adding an extra 0.10 inch to the length would make final assembly much easier and enhance the reliability of the end item.

b. Spacelabs feels that NASA should investigate the possibility of terminating the BGLS in Winchester pins rather than the leads used in the present design. This change would eliminate the need for adding pins to the lead prior to installation in the system and thereby eliminate a solder joint on each end. This change would also eliminate the bend relief. Spacelabs would resistance weld the pins directly to the circuit and seal the area around the pin with epoxy.

Adding to the length of the BGLS would not be necessary if pins were used in place of leads. The reliability of the unit would be enhanced by the elimination of the flexible leads into the body. A sketch of this proposed configuration is included with this report.

6. Quality Assurance and Reliability

All QA and reliability documentation required by the contract was prepared and submitted to NASA during the production of Item 1 of the contract.

DCAS witnessing of all design verification testing and acceptance testing was provided. In-process inspection of the assembly by DCAS was also obtained. No QA or reliability problem areas are known to exist at this time.

7. Documentation

All Spacelabs drawings for the BGLS have been reviewed and updated as necessary to correct errors and to better represent the hardware. A copy of each document, including an updated drawing list, is included with this report.

APPENDIX TO PROGRESS REPORT NO. 2
DESIGN VERIFICATION TEST REPORT

A. Introduction

This report has been prepared in accordance with Paragraph 6.3.12 of the Statement of Work for Contract NAS9-11442 and is a report of the results of testing two Biomedical Ground Lead Systems (BGLS), Spacelabs Part Number 105061, to verify the adequacy of the design.

B. Summary

No problems were encountered in the design verification testing of the two BGLS. The test units met all performance requirements of the DVT test procedure. The test units and data were delivered to NASA/MSC at the conclusion of the test program.

C. Test Report

1. Item Tested

Two BGLS, Serial Numbers 002 and 004, manufactured to Spacelabs Drawing 105061, Rev. A, were submitted to design verification testing.

2. Test Procedure

The two BGLS were design verification tested in accordance with Spacelabs procedure 105069, Rev. A. This procedure was submitted to NASA/MSC and approved prior to the start of testing. Prior to the start of design verification testing, the units were successfully tested

to the requirements of the Acceptance Test Procedure, Drawing 105065.
Rev. B.

3. Parameters Tested

The following tests were made on the two BGLS as a part of the DVT program:

<u>Test Environments</u>	<u>Tests Performed</u>
Acceptance Test (ambient)	Linear resistance Current limiting 50 hour burn-in
120°F High Temperature Operation	Current limiting
40°F Low Temperature Operation	Current limiting
Vibration	Current limiting
Electromagnetic Interference	Current limiting Non-current limiting
Endurance	Current limiting

4. Test Conditions

a. Ambient environment conformance tests were made under the following conditions:

Ambient Pressure	29-31 in Hg
Relative Humidity	<99%
Temperature	50-95°F

b. Environmental tests were made under the following conditions:

High Temperature Exposure	+160 \pm 3.6°F
High Temperature Operation	+120 \pm 3.6°F

Low Temperature Exposure	-55 \pm 3.6 °F
Low Temperature Operation	+40 \pm 3.6 °F
Random Vibration	0.04 g ² /Hz, 20-2000 Hz and ambient
EMI	At ambient to MIL-STD-461 Method RS03
Endurance	Ambient

5. Following are copies of the test data taken during the acceptance and design verification testing of the two DVT units. Copies of these data, except for the Approved Engineering Lab report on EMI and vibration testing, were included in the data packages submitted to NASA/MSD with the units.

SPACELABS, INC.
PROGRESS REPORT NO. 3

This progress report covers the period from 7/17/71 through 10/29/71.

1. General Progress

Spacelabs requested that the BGLS body length for Phase II be extended 0.1 inch. This request was granted by NASA on 10/21/71. Spacelabs expects to issue a procurement order for new bodies during the first week of November. Electronic parts procurement will begin as soon as component specifications are approved by NASA. Component specifications are included with this progress report for NASA review. Spacelabs received notice of Mr. S. Luczkowski's appointment as Technical Monitor for Phase II of the contract and that the critical design review requirement of the contract has been deleted.

2. QA and Reliability

Spacelabs has selected DCA Reliability Laboratory, 1069 East Meadow Circle Palo Alto, California to perform reliability testing of all components in accordance with the component specifications. If the selection of this lab or the specification test requirements are not satisfactory to NASA, Spacelabs must be notified immediately.

3. Documentation

Drawings affected by the change in body length and the acceptance test procedure have been revised and copies are included with this report. No documentation problems are known to exist at this time.

4. Problem Areas

Spacelabs has been unable to duplicate the failure at NASA/MSO of BGLS' #003 and 007. Authority has been granted to use destructive test methods to determine the failure cause. The problem units were subjected to elevated and lowered temperatures (-40°F/+160°F), low pressure (29 psig) with no evidence of failure. Spacelabs will proceed with the dismantling of one of the units in an effort to isolate the problem.

SPACELABS, INC.
PROGRESS REPORT NO. 4

This progress report covers the period from 10/30 through 11/30/71.

1. General Progress

All electronic components for the 50 flight BGLS were ordered. All components are due to be received in December except for the Unitorde diodes. The diodes are due to be shipped from the manufacturer on 12/28/71. Based on past experience, Spacelabs expects these parts will not be received until the first or second week of January 1972. Because of testing required after receipt, the diodes may cause a 2-3 week final end item delivery slippage.

2. QA and Reliability

Testing of parts is proceeding. Environmental Services Co. of Santa Ana is being used for component testing. Spacelabs chose to use this test lab because it is geographically closer to Spacelabs, thus allowing for better surveillance.

3. Documentation

The Qualification Test Procedure shall be prepared during December and submitted to NASA for review and approval. A copy of the latest program schedule is included with this report.

4. Problem Areas

Spacelabs isolated the problem which caused the failure of the prototype BGLS and submitted a detailed report to NASA. It was determined that this failure can be prevented from occurring in the flight BGLS. No other problem areas exist at this time.

SPACELABS, INC. PROGRAM SCHEDULE

5352	1971												1972											
	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
BIOLOGICAL GROUND LEAD SYSTEM	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28	4	11
50 FLIGHT UNITS																								
TECHNICAL PHASE I PROBLEMS																								
RECEIVED AS REQ'D - WELDING DRAWINGS																								
PREPARE PARTS SPECIFICATIONS																								
ORDER PARTS																								
RECEIVE PARTS																								
TEST PARTS																								
PREPARE QUAL TEST PROCEDURE																								
EXP 2 QUAL UNITS																								
QUAL TEST																								
QUAL TEST REPORT																								
FAB FLIGHT UNITS																								
DELIVER FLIGHT UNITS																								
FINAL REPORT																								

ORIGINAL SCHEDULE USED SCHEDULE DUE TO PARTS DELAYS

SPACELABS, INC.
PROGRESS REPORT NO. 5

This progress report covers the period from 12/1/71 through 1/10/72.

1. General Progress

The Unitrode diodes are due to be shipped on 1/12/72 so the final phases of component reliability testing should commence no later than 1/17/72. Based upon receipt of the diodes as promised and no problems with testing, Spacelabs should start fabrication of the qualification units during the week ending 2/18/72. Final delivery of flight BGLS will be about one month late (3/24/72).

2. Documentation

The qualification test procedure is being final typed and will be submitted to NASA/MSC during January.

3. QA and Reliability

No problems exist in this area.

4. Work to be Accomplished During the Next Reporting Period

Testing of electronic components shall be completed and parts shall be kitted for production of 50 BGLS. Weld schedules shall be established for each component lead type. The qualification test procedure shall be submitted to NASA/MSC for approval.

SPACELABS, INC.
PROGRESS REPORT NO. 6

This progress report covers the period from 1/11 through 2/9/72.

1. General Progress

The procurement effort for electronic parts was completed with the receipt of the Unitrode diodes on 1/18/72. All remaining electronic parts are expected back from the test lab on 2/11/72. In response to a Manned Spacecraft Center interest in deleting the qualification testing of BGLS and changing the classification of item number 2 of the contract (50 BGLS) from "flight" to "Class II" equipment, Spacelabs submitted a proposed contract change to NASA/MSC on 1/21/72. Fabrication of the two qual units will not be started during the week of 2/18/72 as reported in the last progress report. With acceptance of the Spacelabs proposal, fabrication of the 50 production units will be started during that week. Final delivery will probably still be on 3/24/72.

2. Documentation

The qualification test procedure was completed on schedule but has not been submitted to NASA/MSC because of the developments mentioned in Paragraph 1 of this report.

3. QA and Reliability

No problems exist in this area.

4. Work to be Accomplished During the Next Reporting Period

Work on weld schedules will be completed and fabrication of 50 BGLS will be started.

SPACELABS, INC.
PROGRESS REPORT NO. 7

1. General Progress

During this period the contract was modified (#3S) to delete qualification testing, end item specification, cleaning and packaging requirements, and changing the 50 BGLS from "flight" to "production" units. In light of this change, and the failure of a large percentage of the PF539 transistors to meet the high-reliability test requirements, Spacelabs has requested the use of unscreened PF539 transistors in 15 of the BGLS. This change is to be added to the contract modification by NASA/MSD. The modification was signed by Spacelabs and returned to the customer.

2. Schedule

Due to difficulties in obtaining more transistors and workload scheduling problems Spacelabs would like to extend the delivery schedule to April 28, 1972. This will enable Spacelabs to obtain replacement parts and process all 50 units through the final processes as a single batch. The transistors will not be available until the week of March 27, 1972.

3. QA and Reliability

The designated DCASR representative inspected the welding of the first 33 units during the period. The failure of the PF539 transistors to meet the high reliability test requirements was due to out-of-tolerance leakages ($> 10 \mu a$) following acceleration testing. This was due to the fact that the device is packaged in a much smaller than normal package to fit into the

BGLS. If the need for flight qualified BGLS should come about, a small increase in size would eliminate this problem.

4. Work to be Accomplished in the Next Reporting Period

After the new parts are received, the remaining units will be completed and all units will be final processed. If the parts are received on schedule, final acceptance testing should take place during the week of April 10, 1972.

5/1/72
BGLS
Contract NAS 9-11442

SPACELABS, INC.
PROGRESS REPORT NO. 8

This progress report covers the period from 3/10/72 through 4/28/72.

1. General Progress

The transistors needed to complete the job were received a week later than reported in the last progress report. The remaining 17 BGLS were assembled and welded during the week ending 4/28/72. The delegated DCAS representative performed source inspection of the in-process work.

2. Work to be Accomplished During the Next Reporting Period

All 50 of the BGLS shall be encapsulated in their potting cases during the week ending 5/5/72. End item acceptance testing will start during the same week.

3. Delivery

It is estimated that end item testing will require about two weeks. Delivery of the 50 BGLS should be made by 5/19/72.

5/24/72
BGLS
NAS 9-11442

SPACELABS, INC.
PROGRESS REPORT NO. 9

This progress report covers the period from 4/29 through 5/22/72.

1. General Progress

All 50 of the BGLS were encapsulated in their potting cases. End item testing started on May 4, 1972 with the 50 hour burn-in. A maximum of 15 units can be "burned-in" at once so burn-in was completed on 5/13/72. The functional testing phase of end item testing was performed during the week ending 5/19/72.

2. Delivery

The units were packaged and shipped to NASA/MSC on 5/22/72 on DD250 #SL00003Z.

3. Summary

No unusual problems were encountered in the final fabrication of the units. Final assembly was found to go much smoother with the use of the elongated potting case.

This is the last progress report for this contract.